SEISMIC RESPONSE OF 4-LEGGED FIXED OFFSHORE STRUCTURE IN MALAYSIA DUE TO SURROUNDING EARTHQUAKE

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ABSTRACT

Fixed offshore structure in Malaysia region are placing more emphasis on wind and wave effects analysis rather than seismic effect. However, Malaysia actually experienced tremors due to the earthquakes occurred in the neighbouring countries. Thus, the main objective of this study is tantamount to investigate the seismic vulnerability of existing fixed offshore structures in Malaysia region and determine the necessity of seismic design consideration for offshore structure in Malaysia. With this, a finite element seismic response simulation of a typical 4-legged fixed offshore structure using SAP2000 has been presented. Moreover, free vibration, time history and response spectrum analysis have been carried out and compared throughout this study. However, there is an assumption have been made when doing the 3D model of the structure. The fixed offshore platform structure is fixed to the ground instead of pilled and the soil interaction was neglected. Generally, fixed offshore structures in Malaysia region are capable of resisting this low seismic activity based on the study. This happens because the design of fixed offshore structures for environmental loading, can provide sufficient resistance against potential low seismic effects.

ABSTRAK

Struktur luar pantai di sekitar Malaysia direkabentuk dengan menekankan pada analisis angin dan kesan gelombang berbanding dengan kesan gempa bumi. Namun demikian, Malaysia sebenarnya mengalami gegaran akibat daripada gempa bumi yang berlaku di negara-negara jiran. Oleh itu, objektif utama kajian ini adalah untuk menyiasat ketahanlasakan dan kelemahan struktur luar pantai di sekitar Malaysia dan seterusnya menentukan keperluan seismik rekabentuk balasan bagi struktur sekitar Malaysia. Dengan ini, simulasi respons seismik tetap struktur luar pantai telah dibentangkan dengan menggunakan SAP2000. Selain itu, percuma getaran, masa sejarah dan analisis spektrum respons telah dijalankan dan berbanding sepanjang kajian ini. Walau bagaimanapun, terdapat suatu andaian yang telah dibuat apabila melakukan model 3D struktur. Struktur luar pantai tetap ke tanah bukannya menggunakan pilled dan interaksi tanah diabaikan. Secara umum, struktur luar pantai di rantau Malaysia berupaya melawan aktiviti seismik rendah berdasarkan kajian yang dijalankan. Ini adalah kerana rekabentuk struktur luar pantai mengambilkira beban alm sekitar yang agak berbeza dan besar daripada struktur biasa dan ini memberikan keupayaan lebih kepada struktur luar pantai ini untuk menanggung beban gempa bumi yang rendah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

mm	Millimeter
mm^2	Millimeter square
mm^3	Millimeter cube
mm^4	Bisquare Millimeter
s	second
kg	Kilogram
kg/m^3	Kilogram per meter cube
N	Newton
kN	Kilo newton
MN	Mega Newton
N/m	Newton per meter
N/mm^2	Newton per millimeter square
kN/m^2	Kilo newton per meter square
kN/m^3	Kilo newton per meter cube
kNm	Kilo newton meter
m/s	Meter per second
g	Gal
Hz	Hertz

LIST OF ABBREVIATIONS

EN	European Standards
ASTM	American Society for Testing and Materials
AISC	American Institute of Steel Construction Specification for design, fabrication and erection of structural steel building
M_L	Local Magnitude Scale
Ms	Surface Wave Magnitude Scale
M_w	Moment Magnitude Scale
API	American Petroleum Institute
V	Self-weight of the topside and structure
M_V	Moment with eccentric loading
L_B	Lateral loads on structure due to wind
L_C	Lateral loads on structure due to currents
L_W	Lateral loads on structure due to waves
M_B	Moments that is related to wind lateral loadings
M_C	Moments that is related to current lateral loadings
L_W	Cyclic loading caused by waves
M_W	Cyclic moment caused by waves
F	Wind force
ρ	Mass density of air
U	Wind speed
A	Area
F_w	Hydrodynamic force vector per unit length
F_D	Drag force per unit length

F_I	Inertial force per unit length
C_d	Drag coefficient
w	Density of water
C_m	Coefficient of inertia
k	Stiffness
T	Natural Period
f	Natural Frequency
MMD	Meteorological Malaysia Department
E	Young Modulus
G	Shear Modulus
FVA	Free Vibration Analysis
DL	Dead Load
LL	Live Load
EL	Environmental Load
TH	Time History
RS	Response Spectrum
I	Moment of Inertia
f_y	Yield Strength
f_u	Ultimate Strength
V_{Ed}	Maximum design shear force
$V_{c,Rd}$	Shear resistance
f_v	Shear stress
F_v	Allowable shear stress
M_{ed}	Maximum external design moment
M_{rd}	Moment resistance

f_b	Bending stress
F_b	Allowable bending stress
t	Thickness
d	Diameter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Earthquakes are one of the world's most devastating and frightening natural disasters. Undoubtedly, we are deeply clear of the hazards, effect and damage caused by this unpredicted earthquake. Basically, earthquake does not kill people, but collapsed buildings and their content do. The greatest hazard in the earthquake is the collapse or fall of man-made and natural structures that caused the extensive loss of life and property. As a result, the seismic effects may not only consider in the countries that have a high risk of a strong earthquake, but also for those countries that are subject to low-to-moderate earthquake for instance like Malaysia since the power of the earthquake has shown us it is unpredicted (Ramli & Adnan, 2004).

Most of the Malaysians may feel that the country is generally free from any major active seismic activities, as a consequence of its strategic location. In fact, positioned at the periphery of the ring of fire and beside the Philippines and Indonesia, two neighbouring countries which have seen violent occurrences of seismological activities, the possibility of being jolted by moderate earthquake cannot be excluded. Moreover, Malaysian Meteorological Department (MetMalaysia) had detected the occurrence of eight earthquakes in East Malaysia which in the magnitude range of 2 to 4.5 Richter scale in the year 2012 (The Malaysian Insider, 2013). Even the Malaysia Peninsula has experienced earthquakes of local origin which associated with active fault that happens in Bukit Tinggi area from year 2007 to 2009 (New Straits Times, 2012).

The exploration and production activities in oil and gas industry remain vital for economy in Malaysia, where the fixed offshore platforms involve the most in the operation (Aulov & Liew, 2013). But then, the current Malaysian offshore structural design practice focused more on wind and wave effects analysis rather than seismic effect, even the parts of Sabah and Sarawak coastal waters are very close to the seismically active zone.

1.2 PROBLEM STATEMENT

Malaysia is located beyond the seismically active zones, but it is still questionable whether the numerous fixed offshore structures in the Malaysia region shall be designed to withstand an earthquake ground motion. In fact, parts of Sabah and Sarawak coastal waters are very close to the seismically active area and we experienced and felt the tremors truly owing to the earthquakes occurred in the neighbouring countries.

The current Malaysian offshore structural design practices focus more on wind and wave effects analysis rather than seismic effect. But, we cannot ensure the fixed offshore structure is safe at a specific level of earthquake acceleration. Therefore, the necessity of seismic design consideration for fixed offshore structure in Malaysia due to surrounding earthquake should be determined.

1.3 RESEARCH OBJECTIVE

There are many matters that require to be analysed in this research, but the main objectives of this research are:

i. To apply surrounding earthquake ground motion for analysis of an offshore structure in Malaysia

ii. To determine the seismic vulnerability of existing offshore structure in Malaysia

iii. To identify the necessity of the implementation of seismic design consideration for offshore structure in Malaysia due to surrounding earthquake

iv. To determine the seismic design criteria for fixed offshore structure located in Malaysia

1.4 SCOPE OF STUDY

The scopes of this study are:

i. The type of offshore structure used will be 4-legged fixed offshore structure

ii. The case study will be conducted in the surrounding earthquake region that affected the offshore platform in Malaysia

iii. The following seismic analyses have been carried out to determine the seismic response of a fixed offshore structure:

- Free vibration analysis has been carried out to obtain the natural period and the mode shape of the fixed offshore structure

- Time history seismic analysis has been carried out by referring to the time history seismic El Centro, 1940
- Response spectrum seismic analysis has been carried out by using response spectra curves of American Petroleum Institutes, API with earthquake ground motion intensity

iv. The computational analysis and structural modelling software used is SAP 2000

v. The considerations of design criteria are based on the approach of the American Petroleum Institutes, API 1993

1.5 SIGNIFICANCE OF STUDY

Throughout this research, we able to gain some general ideas about the earthquake ground motion and seismic effects of the offshore structure which located in Malaysia. Thus to achieve our main objective which to identify the necessity of the implementation of seismic design consideration for offshore structure in Malaysia due to surrounding earthquake through the determined seismic analyses and seismic vulnerability. The behaviours of fixed offshore structures determined from the study may be used to develop or determine some seismic design criteria for new fixed offshore structures positioned in Malaysia.

In addition, this study able to inform the public on earthquakes and their occurrences in Malaysia and the world so that they are aware of the hazards and risk poses by earthquakes. The importance of the seismic design will be noticeable, and thus the implementation of the seismic design can take note and carry out to reduce the seismic effect like loss of life, injuries and extensive property damage.

CHAPTER 2

LITERATURE REVIEW

2.1 EARTHQUAKE

Earthquakes are one of the world's most devastating and frightening natural hazards that result in great loss of life, injuries, extensive property damage and many of the terrible after effects. Basically, an earthquake is a sudden movement of the earth's crust part, followed and accompanied by a series of shakes or tremors which triggered by the sudden release of strain that has gathered over a lengthy period. For hundreds of millions of years, plate tectonics forces have shaped or formed the earth gradually as the huge plates under Earth's surface move under, over and past one another. The plates are locked or fastened together and unable to release the storing energy at other time. The plates will break free, once the accumulated energy raises strong enough. If an earthquake happens in a populated area, it may trigger numerous deaths and injuries and even extensive property damage.

In truth, earthquake does not kill people, but collapsed buildings and their content do. The greatest hazard in the earthquake is the collapse or fall of man-made and natural structures that caused the extensive loss of life and property. As a result, the seismic effects may not only consider in the countries that have a high risk of a strong earthquake, but also for those countries that are subject to low-to-moderate earthquake for instance like Malaysia since the power of the earthquake has shown us it is unpredicted (Ramli & Adnan, 2004).

2.2 CAUSES OF EARTHQUAKES

2.2.1 Tectonic earthquake

Earthquakes happen from the deformation of the brittle and outer portions of tectonic plates, which the earth's most outer layers of crust and the upper mantle. Heating and cooling of the rock below the tectonic plates, resulting in the convection and thus causing the adjacently overlying plates under the great stresses to move, and bring about the deformation. At the fault interface, the relative plate motion is limited by asperities and friction which are the interlocking areas caused by the protrusions in fault surfaces. Nevertheless, the strain energy builds up in the plates, eventually overcomes the resistance, and triggers slip between the both sides of the fault. This sudden slip, termed as elastic rebound which releases enormous amounts of energy, which comprises the earthquake.

2.2.2 Faults

The phrase fault is used to explain a discontinuity within rock mass, laterally which movement had occurred in the earlier. Plate boundary also represents a type of fault. Lineaments are capable linear surface features and may replicate subsurface phenomena. The lineament could be a joint, a fault or other linear geological phenomena. Generally, faults generate repeated displacements over the geologic time. The movement along the fault may be sometimes sudden or gradual, and thus causing an earthquake.

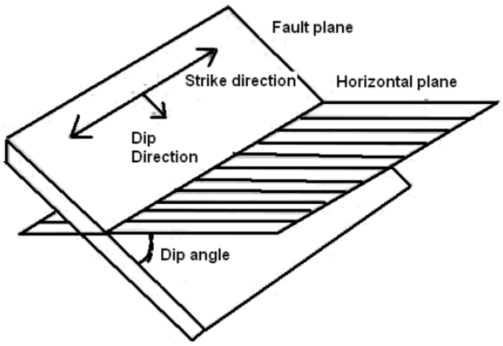

Figure 2.1: Several terminologies associated with rupture plane of fault.

Source: nptel.ac.in [Online image]. (2014). Retrieved September 16, 2014 from http://www.nptel.ac.in/courses/105101004/

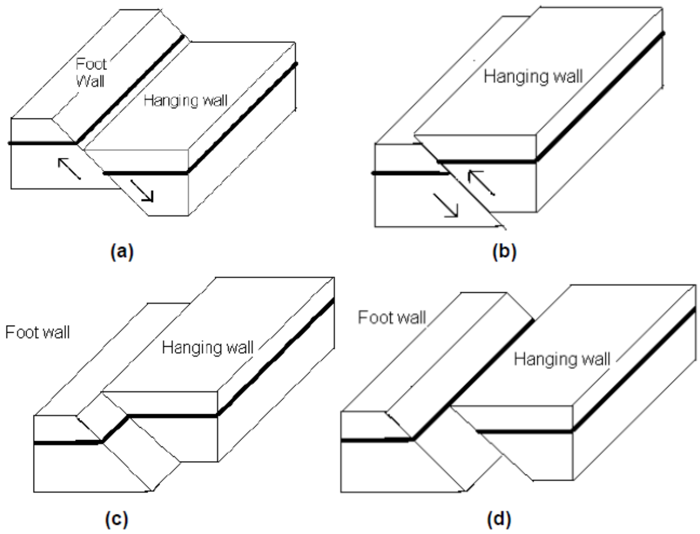

Figure 2.2: Types of faults (a) Normal fault; (b) Reverse fault; (c) Strike-slip fault; (d) Oblique fault.

Source: nptel.ac.in [Online image]. (2014). Retrieved September 16, 2014 from http://www.nptel.ac.in/courses/105101004/

Dip and strike are two of the important parameters associated to describe faults. The strike on the surface of the fault is in a horizontal line direction. The dip, deliberates in a vertical plane at right angles to the strike fault. The hanging wall of the fault indicates to the happen of upper rock surface along which displacement, while the foot wall is the phrase given to that below. Along a fault plane, vertical shift is termed as throw, whereas the horizontal displacement is called the heave.

Faults are categorized in to strike-slip faults, oblique-slip faults and dip-slip faults based on the direction of slippage all along the fault plane. In a strike-slip fault, the movement has occurred along the strike. The movement takes place diagonally along the fault plane in an oblique slip fault. In a case of dip-slip fault, the slippage happened along the dip of the fault. Based on the relative movement of foot walls faults and hanging are categorized into normal, wrench and reverse faults. In a case of a normal fault, the hanging wall has been moved downward relative to footwall. In wrench fault case, the hanging wall or the foot do not shift up or down in the relation to one another. In the reverse fault case, the hanging wall has been moved upward relative to the footwall. Thrust faults, which are the subdivision of reverse faults, tend to bring about the earthquakes.

Faults are nucleating surfaces for seismic activity. The stresses accumulated due to plate movement produces strain mostly along the boundary of the plates. This accumulated strain causes rupture of rocks along the fault plane.

2.3 SEISMIC WAVE

Seismic waves that caused by the faults rupture will result in the acceleration of the ground surface. There are essentially two types of seismic waves which are surface waves and body waves. Both P and S waves are under the category of body waves because they can pass through the interior of Earth. The surface waves are the wave that only detected when close to the earth surface, and they are categorized as Rayleigh waves and

Love waves. Surface waves are the result of the interaction between the earth surface materials and body waves. The types of seismic waves are as follows:

i. P wave (Body wave): The P wave also termed as primary wave, longitudinal wave and a compression wave. P wave is a seismic wave that triggers a series of compressions and dilations of the materials. The P wave is the fastest wave and also the first to reach a site. P waves can pass through both liquids and solids as a compression-dilation type of wave. P wave usually holds the least impact on ground surface movements since soil and rock is essentially resistant to the effects of compression-dilation.

ii. S wave (Body wave): The S wave also termed as the secondary wave, transverse wave and a shear wave. S wave triggers shearing deformations of materials. S waves only can travel and pass through solids because liquids have no shear resistance. The soil and rock shear resistance are normally less than the compression-dilation resistance, resulting S wave travels more slowly through the ground compare with the P wave. In terms of its shear resistance soil is weak and S waves have the greatest effect on the ground surface movements

iii. Rayleigh wave (Surface wave): Rayleigh waves have been defined as being similar to the produce of surface ripples by a rock thrown into the pond. This seismic waves generate both horizontal and vertical displacement of the ground as the outward of surface waves propagate.

iv. Love wave (Surface wave): Love waves are similar to S waves and they are transverse shear waves that travel adjacent to the ground surface.

2.4 EARTHQUAKE MEASUREMENT PARAMETERS

The size of an earthquake could be related to the damage triggered or measurement parameters like intensity and magnitude. These two useful earthquake measurement parameters or definitions of the earthquake's size are sometimes confused.

2.4.1 Intensity

The intensity of seismic indicates the degree of destruction triggered by the earthquake. In other expressions, intensity of an earthquake is a compute or measure of shaking of ground severity and its consequent damage. The intensity is the empirical to some degree or extent because of the extent of damage or destruction that occurs in a construction in a given area that counts on many factors. The factors consist of: (i) the distance from epicenter, (ii) magnitude of earthquake (iii) type of the construction (iv) the compactness of underlying ground, (v) duration of the seismic activity and (vi) the depth of the focus. Intensity of an earthquake is the oldest measure of earthquake activity.

The earthquake intensity scale comprises of a series of specific key responses for example like people awakening, damage to chimneys, movement of furniture and the total destruction. Several earthquake intensity scales have been formed and developed over the last hundred years to evaluate and estimate the earthquakes effect. The most common and popular used is the scale of Modified Mercalli Intensity (MMI). Modified Mercalli Intensity (MMI) scale, composed of 12 rising intensity levels that range from unnoticeable shaking to catastrophic destruction, which defined by Roman numerals. In fact, it is the arbitrary ranking which based on the observed effects, rather providing the mathematical basis. The lower intensity scale numbers are usually dealing with the mode in which the seismic is felt by people. The greater scale numbers are based on observed structural damage.

2.4.2 Magnitude